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Bulletin 90. July, 1910

Georgia Experiment Station

Experiment, Georgia

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Protein Requirements of Growing Cattle Under One Year of Age

By P. N. FLINT

The Bulletins of this Station are sent free to all "persons actually engaged in farming, who make request for same," and to all newspapers in the State. Address MARTIN V. CALVIN, Director, Experiment, Ga.

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PROTEIN REQUIREMENTS OF GROWING CATTLE UNDER ONE YEAR OF AGE.

INTRODUCTION.

A number of Stations have conducted experiments to determine the nutrient requirements of mature cattle, and considerable data have been presented to show that the Wolff-Lehmann feeding standards prescribe a quantity of protein quite in excess of that actually needed. Results indicate, also, that heifers require more nutrients per pound of milk yielded than mature cows. Fewer experiments have been conducted to determine nutrient requirements of growing cattle under one year of age. It seems, however, that this should be a fertile field for investigation, and should prove of great value, since, within certain limits, the capacity of an animal for beef or milk production is determined by the food supply during the growing period of its life.

Per unit of live weight, a growing animal requires a greater quantity of protein than a mature animal. The former requires protein for growth and maintenance, while the latter, except when giving milk or is pregnant, requires protein for maintenance only. While the Wolff-Lehmann feeding standards for mature cows prescribe an amount of protein in excess of that needed, it has been questioned whether or not the same is true in case of the young growing animal.

This bulletin reports the results of one of three years' work directed towards the determination of protein requirements of calves, principally of the dairy type. A considerable number of digestion experiments were conducted during each year in order, primarily, to determine the nitrogen balance under different conditions as to food supply, and whether or not an excessive amount of protein in the ration establishes the "factor of waste." The results of this latter phase of the subject awaits the collection of more data before being published, and for this reason the first two years' work is not herein reported.

PLAN OF EXPERIMENT, 1909-1910.

Twenty three animals, nineteen steers and four heifers, were used in the experiments of this year. One steer and all of the heifers were born at the Station, while the others were purchased from parties living nearby. With the exception of two calves all of them were of the dairy type, with Jersey blood predominating. Of the animals purchased it was impossible to determine their exact ages, but they undoubtedly varied from three to five months of age at the beginning of the experiment. Those taken from the Station herd were of about the same ages as those purchased.

During the preliminary period of 30 days, each animal was fed as prescribed by the Wolff-Lehmann feeding standards. The experiment consisted of two periods of 88 days each. The first period began October 5 and continued until December 31. The second period began January 1 and continued until March 29.

It was the original purpose to feed lot 2 as prescribed by the feeding standards, and lots 1 and 3 twenty five per cent less and twenty five per cent more protein, respectively, than prescribed by those standards, the carbohydrate and fat content of the rations in each case being the same as prescribed by the feeding standards. In calculating the results, however, it was found that none of the animals consumed as much of the digestible food nutrients as was intended.

At feeding time each animal was fastened in a stanchion and the mangers were so constructed that no animal could waste its feed or share with its neighbor. All feeds refused were weighed back each day. The feeds were weighed out on spring balances which weighed to five one-hundredths of a pound. The feeding hours were at six o'clock A. M., and two-thirty o'clock P. M. The weight of each animal was secured by averaging the weights of three consecutive days. New rations were calculated every three weeks on the basis of their weight at that time.

During every other week of the first period, two calves from each lot, the same calves being used each time, were kept in digestion stalls and the urine collected, weighed and analyzed for nitrogen content. Before the close of the experiment one or more complete digestion tests were conducted with each of seven animals.

Table 1. Digestible Food Nutrients Required by Wolff-Lehmann Feeding Standards.

GROWING CATTLE DAIRY BREEDS		Per Day per 1,000 Pounds Live Weight				
		Dry Matter	Digestible Nutrients			
Age Months	Weight lbs.		Protein	Carbohydrates	Ether Ext.	Nutritive Ratio
2–3	150	23	4.0	13.0	2.0	1:4.5
3–6	300	24	3.0	12.8	1.0	1:5.1
6–12	500	27	2.0	12.5	0.5	1:6.8
12–18	700	26	1.8	12.5	0.4	1:7.5
18–24	900	26	1.5	12.0	0.3	1:8.5

Table 1 shows the quantity of dry matter, digestible fool nutrients and nutritive ratio required per 1,000 pounds live weight for animals weighing 150, 300, 500, 700 and 900 pounds respectively. It is seen that the standards prescribe an increasing quantity of dry matter per 1,000 pounds weight until the weight of 700 pounds is reached after which it is decreased to 26 pounds per 1,000 pounds live weight. The standards also prescribe a decreasing quantity of digestible nutrients per 1,000 pounds live weight as the weight increases. The digestible protein, however, is decreased faster than the digestible carbohydrates. This results in a widening of the nutritive ratio as the animal grows older and increases in weight, and is in accord with the fact already stated, namely, that a young animal requires more protein per unit of weight than a mature animal.

In Farmers Bulletin 346, Armsby points out that the common method of comparing feeding stuffs on the basis of the digestible matter they contain to be in error. For example, two feeds containing the same quantity of digestible matter may not be of equal value to the organism on account of the fact that one may require a greater expenditure of energy in digestion than the other. The correct measure of the value of a feeding stuff is the "energy which remains after deducting the losses in the unburned material of the excreta and the energy expended in extracting the fuel materials from the feeds and transforming them into substances which the body can use or store up." The remaining energy is known as energy value and is expressed in terms of therms. A therm is the quantity of heat required to raise the temperature of 1,000 kilograms of water (2,204.6 pounds) one degree centigrade. For the purpose of a more correct comparison the energy values of the various rations fed are given in this bulletin.

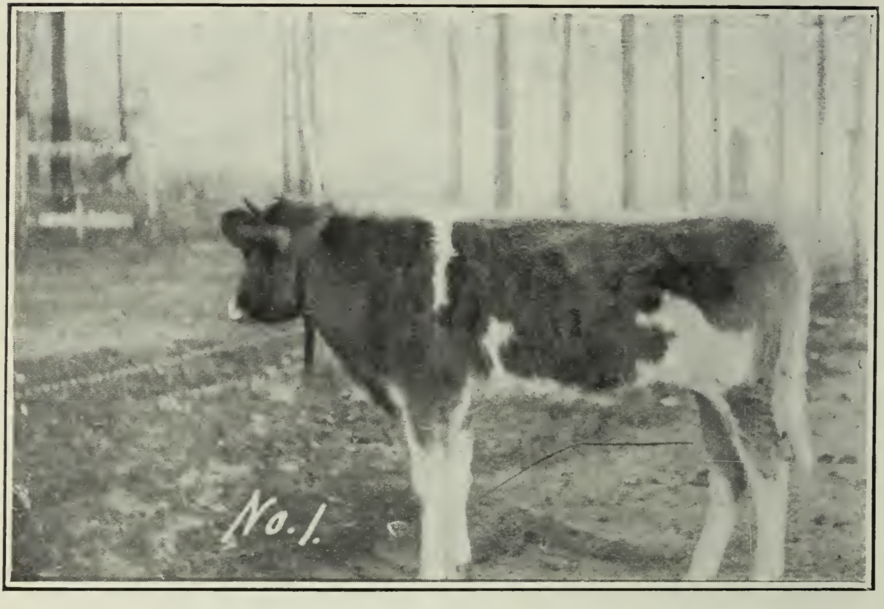
Table 2. Dry matter, Digestible Nutrients, and Energy Values of Feeds.

FEEDSTUFFS	Dry Matter Per Hundred Pounds	Digesiible Nutrients Per 100 Pounds			Energy Values Per Hundred Pouuds
		Protein	Carbohydrates	Fats	
Corn Meal.....	86.95	5.78	67.10	3.33	88.84
Linseed Meal..	88.73	25.63	42.57	2.53	74.67
Alfalfa Hay....	86.60	11.47	36.24	0.74	34.41
Oat Straw.....	85.90	0.78	31.59	0.48	21.21

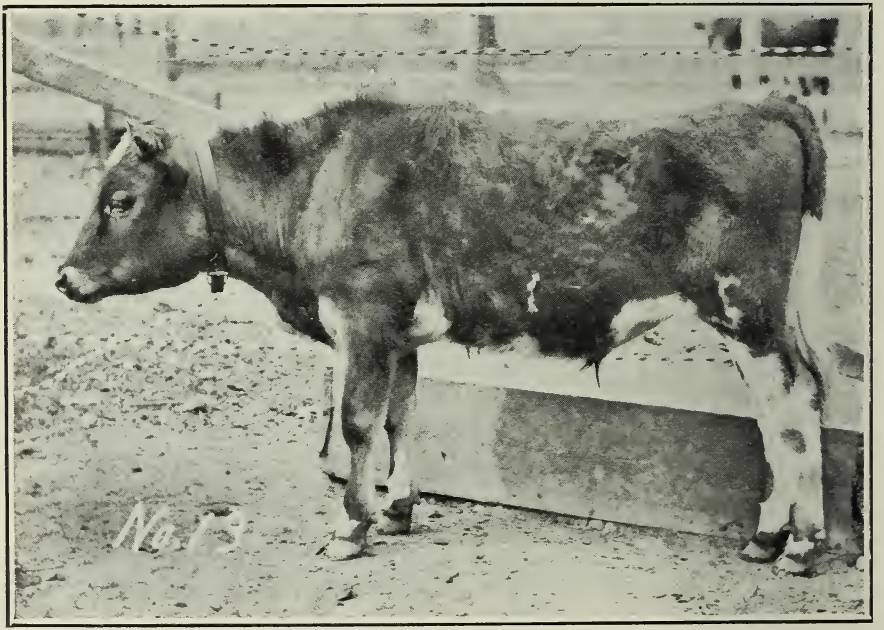
The digestible nutrients of the feeds used were calculated on the basis of their composition as determined by the chemical department, and the average percentage digestibility as given in Henry's Feeds and Feeding. The dry matter was determined by the chemical department and the energy values were taken from Farmers Bulletin 346.

Table 3. Average Daily Rations, Average Weights and Gains, First Period, 88 days.

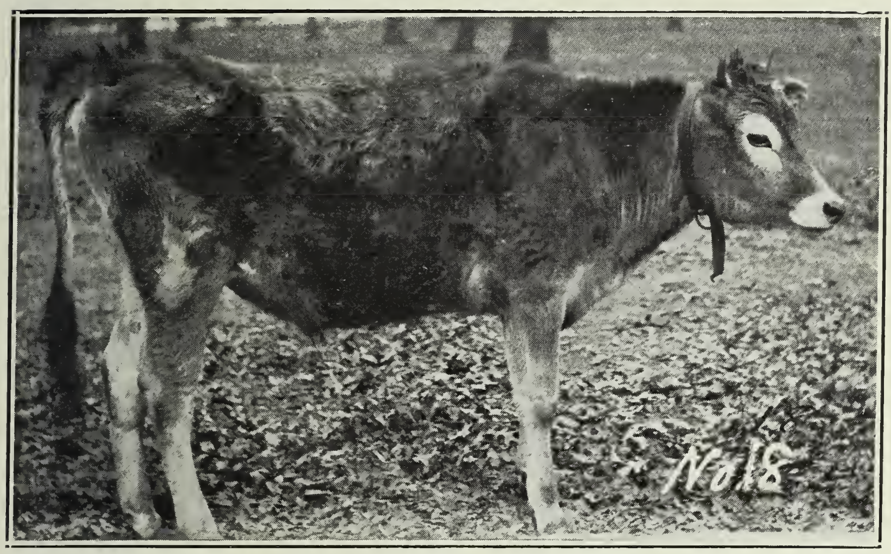
Lot No.	No. of Animal	Corn Meal Daily	Linsesd Meal Daily	Alfalfa Hay Daily	Oat Straw Daily	Average Weight	Gain 88 Days
		Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
Lot 1.	7	1.04	0.24	1.40		108.5	45.0
	14	1.92	0.03	2.62		168.9	41.7
	1	2.54	0.22	2.38	0.26	206.2	89.7
	8	2.47	0.30	2.61	0.39	233.0	75.4
	13	2.56	0.43	2.39	0.89	250.1	64.9
	3	2.50	0.49	2.40	1.04	266.0	96.0
	18	3.32	0.40	2.59	1.26	331.8	73.0
Lot 2.	2	0.86	0.60	1.67		117.2	43.7
	24	0.99	0.52	2.49		136.3	48.6
	16	1.58	0.88	2.30		182.4	75.2
	22	2.57	1.00	2.16		219.7	90.7
	10	1.86	0.51	3.58		224.9	61.7
	11	1.88	0.69	3.17		226.2	68.3
	6	2.19	0.77	3.15		226.9	79.2
	4	3.06	1.01	2.48		257.8	111.5
Lot 3.	12	1.04	1.11	2.83		165.2	69.0
	23	1.13	1.11	2.87		167.2	77.0
	17	1.32	1.01	2.59		174.2	79.1
	5	1.18	1.15	4.01		209.0	98.0
	15	1.40	1.22	3.88		222.5	115.9
	19	1.44	1.47	4.06		245.0	108.0
	21	1.96	1.61	3.55	0.31	270.0	106.7
	9	1.89	1.82	2.87	0.16	275.9	133.7



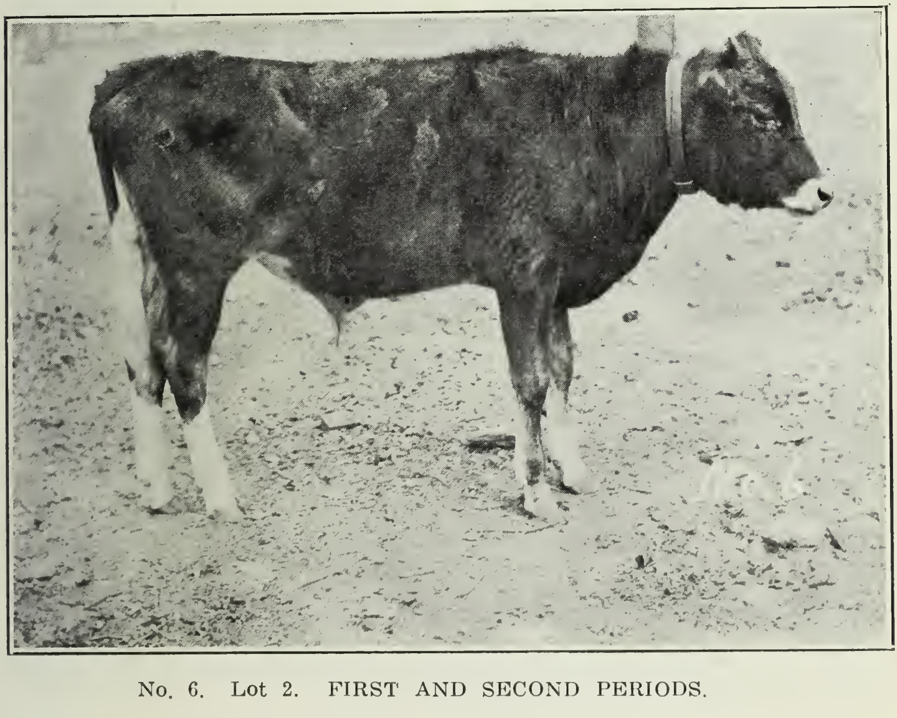
No. 1. Lot 1. FIRST PERIOD.



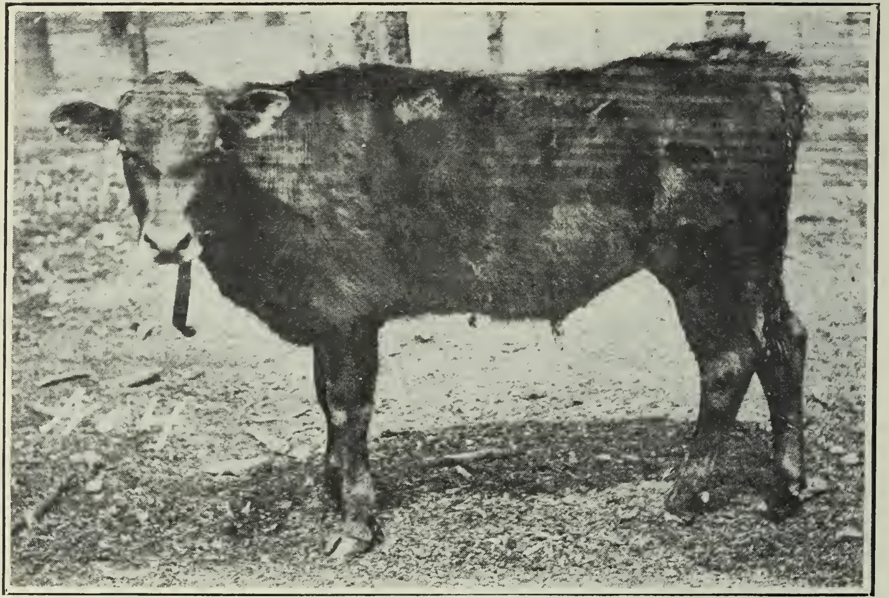
No. 13. Lot 1. FIRST PERIOD.



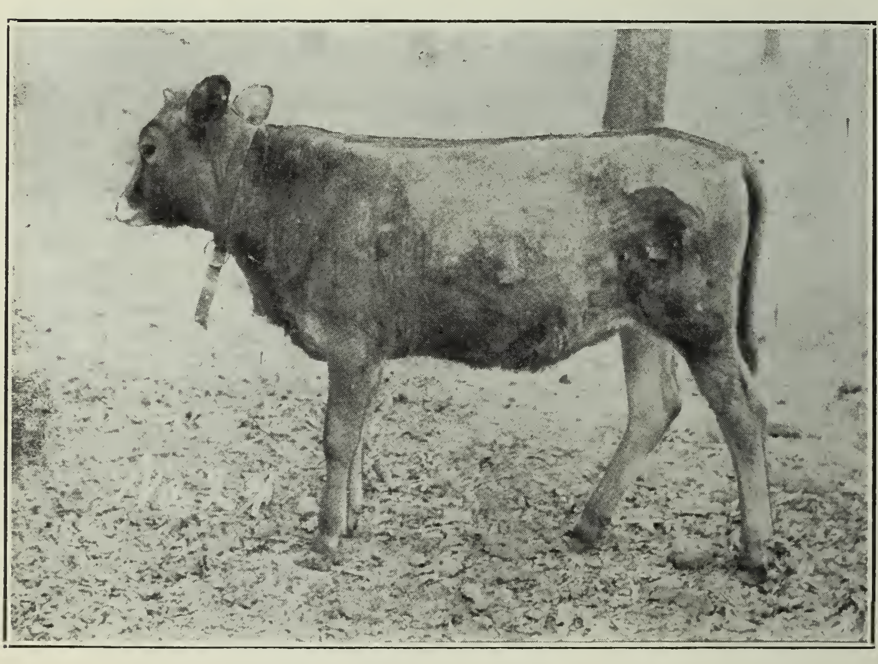
No. 18. Lot 1. FIRST AND SECOND PERIODS.



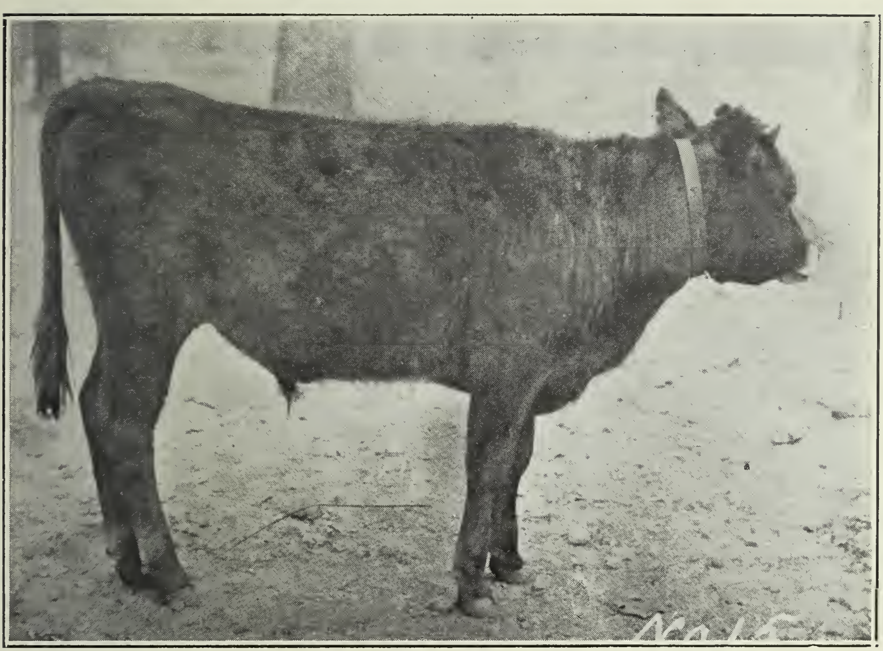
No. 6. Lot 2. FIRST AND SECOND PERIODS.



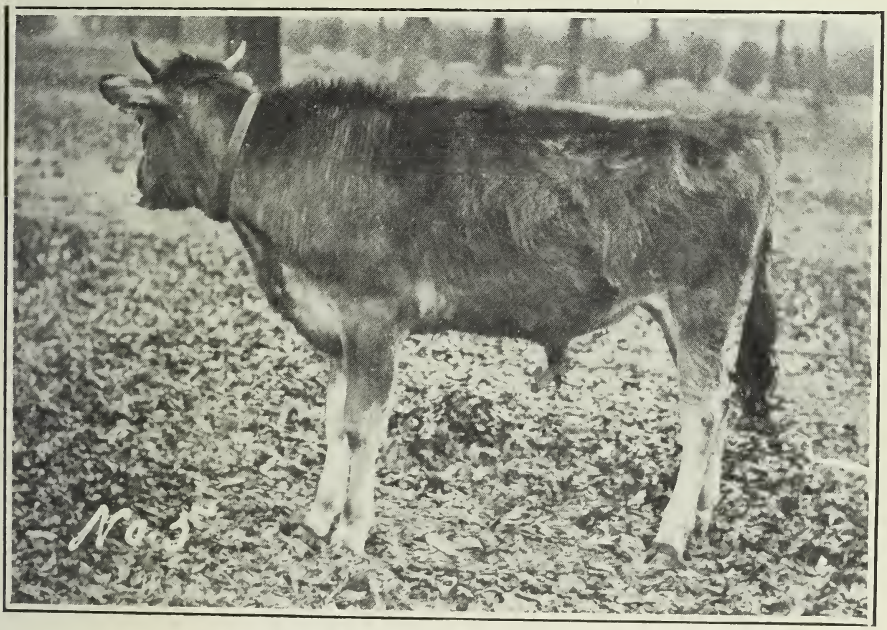
No. 4. Lot 2. FIRST PERIOD.



No. 24. Lot 2. FIRST AND SECOND PERIODS.



No. 15. Lot 3. FIRST PERIOD.



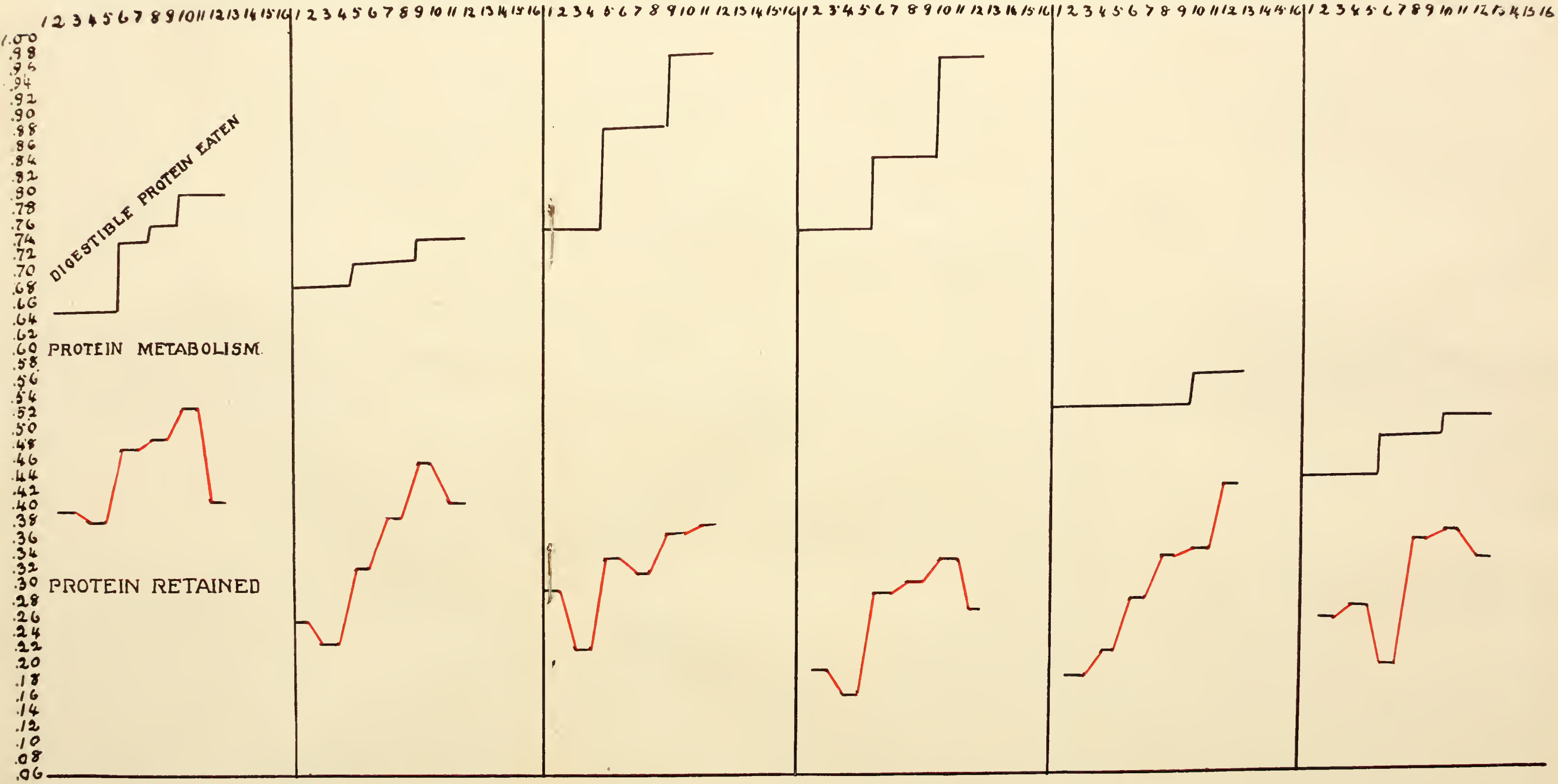
No. 5. Lot 3. FIRST PERIOD.

No. 9. Lot 3. FIRST AND SECOND PERIODS.

No. 19. Lot 3. FIRST PERIOD.

CHART NO. 1—1st Period October 5th to December 31, 1909, 88 days.

Black lines represent digestable protein in feed. Red and Black lines represents protein metobolism. Black parts representing average protein metobolism for one week. Red representing imaginary curve. Horizontal numerals along top represent weeks. Vertical column of numerals represents digestable protein in feed and also pretein metobolism.



CALF No. 4.
Gain 111.4
Average Weight . 257.8

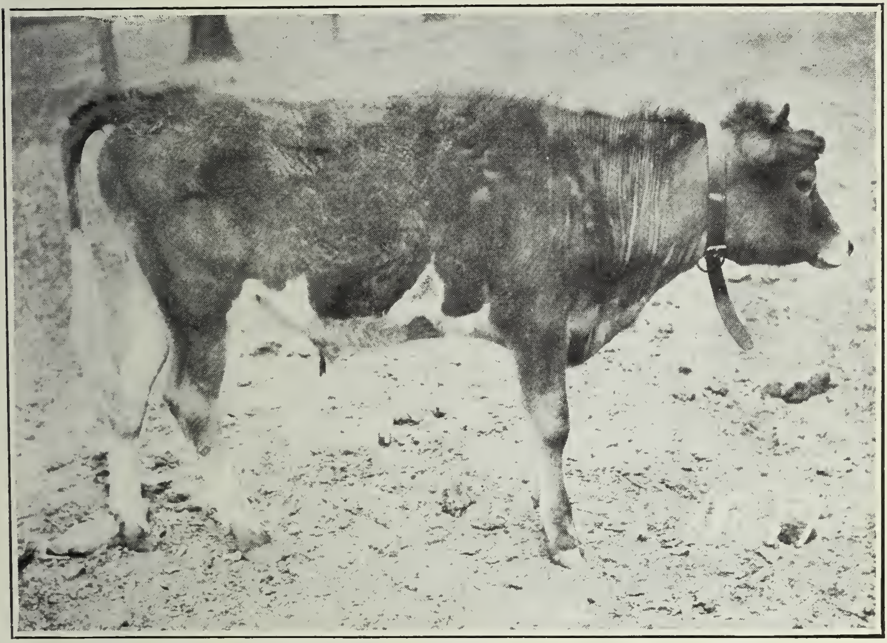
CALF No. 6.
Gain 79.2
Average Weight 226.9

CALF No. 15.
Gain 115.0
Average Weight 222.5

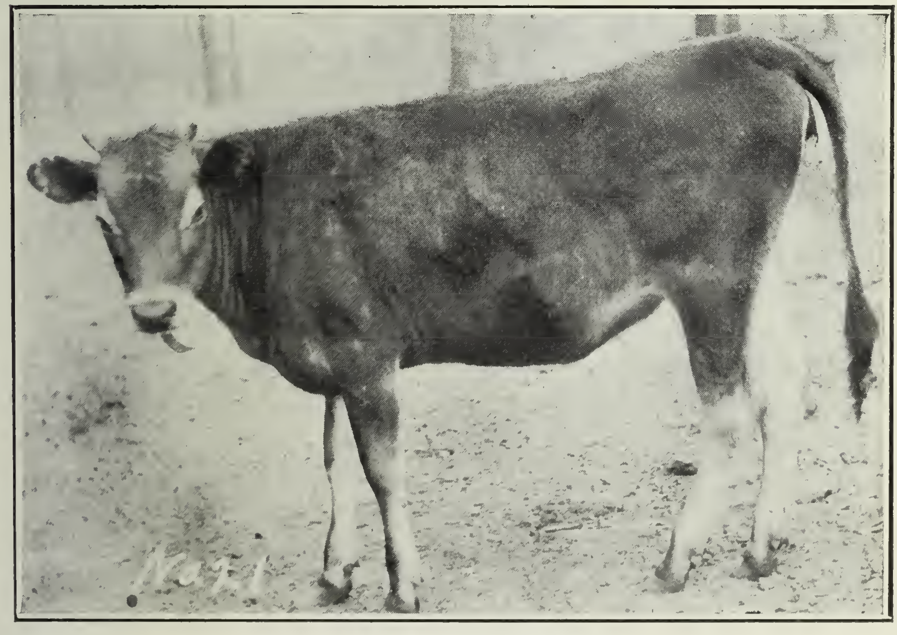
CAFL No. 5.
Gain 98.0
Average Weight . 209.0

CALF No. 13.
Gain 64.9
Average Weight 250.1

CALF No. 1.
Gain 89.7
Average Weight 206.2



No. 17. Lot 3. FIRST AND SECOND PERIODS.



No. 21. Lot 3. FIRST PERIOD.

Table 4. Average Daily Rations, Average Weights, and Gains. Second Period, 88 days.

Lot No.	No. of Animal	Corn Meal Daily	Linseed Meal Daily	Alfalfa Hay Daily	Oat Straw Daily	Average Weight	Gain 88 Days
		Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
Lot 1.	7	2.24	0.16	2 18		165.5	69.0
	8	3.57	0.05	3 30	0 58	309.5	77.6
	18	5.34	0.05	2.58	0.72	398.6	60.0
Lot 2.	24	1.98	0.81	2.53		196.5	71.7
	16	2.93	0.95	2 90		274.3	108.6
	10	2.59	0.62	4.33	0.18	302.7	93.9
	11	2 70	0.87	3.22	0 21	308.7	96.7
	6	3.36	0.95	3.14	0.53	322.1	111 1
Lot 3.	23	1.81	1.43	3.97		251.9	92.3
	17	2.10	1.82	2.53	0.20	262.9	98.3
	22	2.78	1.79	4.05	0.29	316.8	103.6
	9	3 91	1.54	4.38	0.49	418.4	151.3

Tables 3 and 4 are presented to give the reader an idea of the relative amounts of the several feedstuffs consumed and gains made by individuals in the three lots.

It is seen that Lot 1 consumed the greatest proportion of the carbohydrate feeds—corn meal and oat straw. Lot 3 consumed the greatest proportion of protein feeds—linseed meal and alfalfa hay. Lot 2 consumed a greater proportion of the protein feeds than lot 1, but a smaller proportion than Lot 3. On the other hand Lot 2 consumed a smaller proportion of the carbohydrate feeds than Lot 1, but a greater proportion than Lot 3. Since the various animals in each lot were fed on the basis of their live weight, using the feeding standards as a guide, the tables afford a good study not only of individuality but they are a help to the feeder when using those particular feeds. A discussion of the relative gains is made in connection with tables 5 and 6.

At the beginning of the second period four animals from Lot 1, three from Lot 2, and four from Lot 3 were taken out of their respective lots and fed upon a different basis. With the exception of one, No. 19, a report is not herein made of the tests with these animals.

Table 5. Dry Matter, Digestible Protein, and Energy Values of Average Rations, First Period, 88 days. Also Average Weights and Gains.

Lot No.	No. of Animal.	Dry Matter. Pounds	Digestable Protein. Pounds	Energy Value Terms	Average Weight. Pounds	Gain 88 Days Pounds
LOT 1	7	2.33	0.28	1.59	108.5	45.0
	14	3.97	0.42	2.63	168.9	41.7
	1	4 69	0.48	3.30	206.2	89.7
	8	5.01	0.52	3.40	233.0	75.4
	13	5.44	0.54	3.61	250.1	64.9
	3	5.58	0.55	3.63	266.0	96.0
	18	6.57	0.60	4.41	331.9	73.0
	Average . .	4.80	0.48	3.22	223.5	69.4
	Avg. per 1000 lbs. weight	21.47	2.15	14.40		
LOT 2	2	2.72	0.40	1.78	117.2	43.7
	24	3.48	0.48	2.13	136.3	48.6
	16	4.14	0.57	2.85	182.4	75.2
	22	5.00	0.65	3.77	219.7	90.7
	10	5.18	0.65	3.27	224.9	61.7
	11	5.01	0.64	3.28	226.2	68.3
	6	5.32	0.69	3.61	226.9	79.2
	4	5.61	0.72	4.28	257.8	111.5
	Average . .	4.56	0.60	3.12	198.9	72.4
	Av. per 1000 lbs. weight	22 92	3.02	15.69		
LOT 3	12	4.34	0.67	2.72	165.2	69.0
	23	4.55	0.68	2.82	167.2	77.0
	17	4.59	0.63	2.82	174.2	79.1
	5	5.52	0.82	3.29	209.0	98.0
	15	5.66	0.84	3.49	222.5	115.9
	19	6.07	0.93	3.77	245.0	108.0
	21	6.47	0.94	4.23	270 0	106.7
	9	5.88	0 91	4.06	275.9	133.7
	Average . .	5.37	0.80	3.40	216.1	98.4
	Av. per 1000 lbs. weight	24 66	3 70	15 73		

Table 5 shows that the average daily quantity of digestible protein consumed per lot stands in the same order as the average gains in weight per lot. Lot 1 consumed an average of 0.48 pounds of digestible protein daily; Lot 2. 0.60 pounds; and Lot 3, 0.80 pounds. Lot 1 made an everage gain per animal in 88 days of 69.4 pounds; Lot 2, 72.4 pounds; and Lot 3, 98.4 pounds. However, there was a difference of but 3 pounds per animal between the gains of Lots 1 and 2. The table also shows that there was not much difference in the average energy content of the rations of the three lots—that of Lot 1 was 3.22 therms; Lot 2, 3.12 therms; and Lot 3, 3.40 therms. When calculated per 1,000 pounds live weight, however, the rations of Lots 2 and 3 each contained practically 15.7 therms of energy value, and that of Lot 1, 14.40 therms of energy value. Disregarding individuality then, it would appear that the greater gains made by Lot 3 over Lot 2 were due to the greater protein content of the rations of the former lot. Also the smallest gains, made by Lot 1, would appear to be due to both the lower protein and energy content of the rations of this lot.

Table 6. Dry Matter, Digestible Protein, and Energy Values of Average Rations, Second Period, 88 days. Also Average Weights and Gains.

Lot No.	Number of animal	Dry Matter	Digestible protein	Energy value	Average weight	Gain 88 days
		pounds	pounds	therms	pounds	pounds
Lot 1	7	3.98	0.41	2.86	165.5	69.0
	8	6.51	0.60	4.47	309.5	77.6
	18	7.54	0.62	5.75	398.3	60.0
	average	6.01	0.54	4.36	291.1	68.9
	avg. per 1,000 lbs. weight	20.65	1.86	14.98		
Lot 2	24	4.63	0.61	3.23	196.5	71.7
	16	5.91	0.75	4.31	274.3	108.6
	10	6.71	0.81	4.29	302.7	98.9
	11	6.09	0.75	4.20	308.7	96.7
	6	6.94	0.80	4.89	322.1	111.1
	average	6.06	0.74	4.18	280.9	96.4
	avg. per 1,000 lbs. weight	21.57	2.63	14.88		
Lot 3	23	6.29	0.93	4.03	251.9	92.3
	17	5.80	0.88	4.13	262.9	98.3
	22	7.75	1.08	5.26	316.8	108.6
	9	9.06	1.13	6.24	418.4	151.3
	average	7.22	1.01	4.92	312.5	111.4
	avg. per 1,000 lbs. weight	23.10	3.23	15.74		
	19	8.38	1.55	5.61	359.3	120.6
	per 1,000 lbs. weight	23.32	4.31	15.61		

Table 6 shows that there was but little difference in energy value between the average rations of Lots 1 and 2, either actual or per 1,000 pounds live weight. The average ration of Lot 1 contained per 1,000 pounds live weight 0.10 therms more energy value than the average ration of Lot 2. In respect to digestible protein, on the other hand, the average ration of Lot 2 contained per 1,000 pounds weight 0.77 pounds more than the average ration of Lot 1. Lot 2 made an average gain per animal in 88 days of 96.4 pounds while the average gain of Lot 1 was but 68.9 pounds. It would appear, therefore, disregarding individuality, that the greater gains of Lot 2 were due to the greater amount of digestible protein consumed.

It is seen that the average gain per animal of Lot 3 was 111.4 pounds, while the gains of Lots 2 and 1 were 96.4 pounds and 68.9 pounds respectively. The greater gain of Lot 3 appears to be due both to the greater quantity of digestible protein and energy value contained in the average ration of that lot.

While during both periods the average gain of Lot 1 was smaller than that of Lots 2 and 3, and the gain of Lot 2 smaller than that of Lot 3, this could have been due, in a large measure at least, to individuality. As shown by table 5 there was but one animal in Lot 2 and five in Lot 3 during the first period which made greater gains than any in Lot 1. Likewise there was but two animals in Lot 3 during the first period that made greater gains than any in Lot 2. As will be shown later, a determination of the nitrogen balance on two animals in each lot, during the first period, indicated that the four animals of Lots 1 and 2 retained, at least, as much protein as those of Lot 3. This being true, and the rations being alike in other respects, we should expect that a smaller quantity of protein than fed to Lot 3 to be equally as efficient for the production of gains. To prove this would require a large number of animals in each lot in order to eliminate the factor of individuality.

Calf No. 4 of Lot 2 during the first period made a gain of 111.5 pounds on a ration containing 0.72 pounds of digestible protein and 4.28 therms energy value while calf No. 21 of Lot 3 made 4.8 pounds less gain on a ration containing about the same amount of energy value but 0.22 pounds more digestible protein. Calf No. 1 of Lot 1 during the same period made but 8.3 pounds less gain than No. 5 of Lot 3 on a ration containing practically the same amount of energy value but 0.34 pounds less digestible protein. While there was but 9.1 pounds difference in the gains of No. 19 of Lot 3 and No. 6 of Lot 2 during the second period yet the average ration of No. 19 contained 0.70 pounds more digestible protein and 0.72 therms more energy value. This shows that either some individuals can make the same or greater growth on a smaller quantity of protein than others, or that as long as the protein supply is adequate to supply material for growth a larger quantity increases the rate of growth only to a minor degree. No one, who was familiar with the animals used in the test, would have doubted that No. 9 possessed the ability to make better use of his feed than any other animal. (See photo.)

It appears quite certain that the protein supply was not sufficient for best development in case of No. 18. At the beginning of the experiment he gave every evidence of being a good individual but he made only 73 pounds of gain during the first period and 60 pounds during the second period. (See photo.) From table 4 it is seen that his average ration during the second period consisted of 5.34 pounds corn meal, 0.05 pounds linseed meal, 2.58 pounds alfalfa hay and 0.72 pounds oat straw. The ration is deficient in protein feeds. A deficient protein supply limits growth but a surplus does not stimulate growth to any great extent. As will be shown later a protein supply above that required for growth and maintenance is used for fuel material, the nitrogen appearing in the urine.

In dividing the animals into lots at the beginning of the experiment an attempt was made to make them as near uniform as possible. The six least promising individuals were divided between the three lots. These were Nos. 7, 14, 2, 24, 12 and 17. As shown by their gains in weight Nos. 12 and 17 proved to be better individuals than the other four animals. Whether or not this was due to the greater quantity of protein which they consumed is difficult to determine. The author is inclined to believe that individuality had considerable influence.

It is seen by Table 6 that No. 19 was in a lot by himself during the second period. He was fed on a ration containing a high quantity of protein. The energy value per 1,000 pounds live weight was about the same as the average for Lot 3 but his protein supply was 1.07 pounds greater. While he made good gains yet they were not as good as those of No. 9. During the first period when fed on the same basis as No 9. he made 25.7 pounds less gain, and during the second period when fed a greater quantity of protein he made 30.7 pounds less gain. It would appear that the greater protein supply in this case did not serve to increase his gains.

Table 7. Average Rations Compared with that Prescribed by Wolff-Lehmann Feeding Standards. First Period.

		Dry Matter	Digestible Protein	Digestible Carbohydrates plus (Fats X 2 25)	Energy Value	Average Weight	Gain 88 Days
		Pounds	Pounds	Pounds	Therms	Pounds	Pounds
Lot 1	Actually Consumed	4.80	0.48	2.97	3.22	223.5	69.4
	Feeding Standards	5.25	0.78	3.64	....	....	....
	Difference	-0.45	-0.30	-0.67	....	....	....
Lot 2	Actually Consumed	4.56	0.60	2 75	3.12	198.9	72.4
	Feeding Standards	4.64	0.73	3.32	....	....	....
	Difference	-0.08	-0.13	-0.57	....	....	....
Lot 3	Actually Consumed	5.37	0.80	2.97	3.40	216.1	98.4
	Feeding Standards	5.07	0.76	3.55	....	....	....
	Difference	0.30	0.04	-0 58	....	....	....

Table 8. Average Rations Compared with that Prescribed by Wolff-Lehmann Feeding Standards. Second Period.

		Dry Matter	Digestible Protein	Digestible Carbohydrates plus (Fats X 2.25).	Energy Value	Average Weight	Gain 88 days
		Pounds	Pounds	Pounds	Therms	Pounds	Pounds
Lot 1	Actually Consumed	6.01	0.54	3.97	4.36	291.1	68.9
	Feeding Standards	6.98	0.88	4.42	....	....	....
	Difference	-0.97	-0.34	-0.45	....	....	....
Lot 2	Actually Consumed	6.06	0.74	3.70	4.18	280.9	96.4
	Feeding Standards	6.71	0.87	4.32	....	.. ....	....
	Difference	-0 65	-0.13	-0.62	....	....	....
Lot 3	Actually Consumed	7.22	1.01	4.27	4.92	312 5	111.4
	Feeding Standards	7.56	0.92	4.68	... .	....	....
	Difference	-0.34	0.09	-0.41	....	....	....

Tables 7 and 8 show that the average daily rations of each lot during both periods were somewhat lower in digestible carbohydrates plus (fats x 2.25) than prescribed by the feeding standards. The average ration of Lot 1 contained 0.67 pounds less of that food nutrient in the first period and 0.45 pounds less during the second period; Lot 2, 0.57 less in the first period and 0.62 pounds less during the second period; Lot 3, 0.58 pounds less during the first period and 0.41 pounds less during the second period. In respect to digestible protein Lot 1 consumed approximately one-third of a pound less daily of that food nutrient during both periods than required by the feeding standards; Lot 2, 0.13 pounds less during each period; and Lot 3, 0.04 pounds more during the first period and 0.09 pounds more during the second period.

Comparing the average daily rations of the three lots during each period the tables show that considering differences in weight, they vary but slightly in respect to digestible carbohydrates plus (fats x 2.25), but in respect to digestible protein they vary to a considerable extent.

The tables show that during each period the average rations of Lot 3 conformed more nearly to the feeding standards in respect to digestible protein than either of the other lots. This lot also made the greatest gains. However, since the digestible carbohydrates and fats were lower than prescribed by the feeding standards not only in case of Lot 3, but in case of the other two lots as well, it would be erroneous to conclude from the data presented that the Wolff-Lehmann feeding standards do not prescribe too great an amount of protein, because had more carbohydrates been comsumed it is probable that as great gains would have been made on less digestible protein. Also judging by the variations in gains by individuals of the different lots it would be necessary, before true comparisons could be made, to feed a large number of animals in order to eliminate the factor of individuality. These results bring out the fact that no single feeding standard can be devised which will prescribe an amount of digestible food nutrients to meet the exact requirements of all animals.

DIGESTION TESTS AND NITROGEN BALANCE.

During the first period of the experiment two calves from each lot, the same calves being used each time, were placed in digestion stalls every other week and their urine collected, weighed and analyzed for nitrogen content. Beginning with the latter part of the first period and continuing until the end of the second period, one animal was placed in the digestion stall every other week and a complete digestion test conducted. Before the end of the experiment one or more complete digestion tests were conducted with each of seven animals. Thus during the first period of the experiment the urine from six calves was collected during 42 out of the 88 days of this period and the average daily protein metabolism during this time is given in table 9. The average daily protein metabolism given in table 10 is the result of a seven days test during which time a complete digestion test was conducted.

The digestible nutrients of the feeds during the first period were calculated on the basis of the actual analysis of the feeds and the average percentage digestibility of the nutrients as given in Henry's Feeds and Feeding. The protein digested as given in table 10 is the result of actual digestion tests.

For the collection of the feces an especially prepared rubber duct was attached to the rear of the animal by means of a harness. This conducted the feces into a galvanized tub underneath the stall. The urine was collected by means of a rubber funnel attached to the male animal.

Both the feces and urine were weighed once in twenty-four hours and an average sample taken for analysis. The determinations of the nitrogen in the feces were made upon both the fresh and dried material. An analysis of the urine for nitrogen content was made daily.

Table 9. Summary Table of Determination of Protein Metabolism. Also Digestible Protein and Energy Value in Average Rations, and Average Weights and Gains.

Lot No.	No. of animal	Energy value	Digestible protein	Average daily protein metabolism, 42 days	Average daily protein retained	Average daily protein retained per 1,000 lbs. weight	Avg. weight	Avg. gain daily
		Therms	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
Lot 1	13	3.61	0.54	0.24	0.30	1.20	250.1	0.74
	1	3.30	0.48	0.17	0.31	1.50	206.2	1.02
Lot 2	4	4.28	0.72	0.29	0.43	1.67	257.8	1.27
	6	3.61	0.69	0.36	0.33	1.45	226.9	0.90
Lot 3	15	3.49	0.84	0.54	0.30	1.35	222.5	1.32
	5	3.29	0.82	0.58	0.24	1.10	209.0	1.11

From table 9 it is seen that Nos. 15 and 5 consumed the greatest daily allowance of digestible protein and it is also seen that their protein metabolism is greatest. The table also shows that Nos. 13 and 1 consumed the smallest daily allowance of digestible protein and their protein metabolism is smallest. In other words, an increased protein supply resulted in an increased protein metabolism. In the column headed protein retained and also protein retained per 1,000 pounds weight it is seen that there is not a great deal of difference in the quantity of protein retained by the different animals. At least calves Nos. 5 and 15 which received the greatest supply of protein did not retain a correspondingly greater amount. Nor did the smaller protein supply of Nos. 13 and 1 cause them to retain a smaller amount. Had the protein supply of these two animals been still further reduced to a maintenance supply there would have been a decreased protein metabolism. From these results it would appear that the protein supply of Nos. 13 and 1 was adequate for normal development.

There was not much difference in the gains in weight between Nos. 1 and 5, yet No. 1 received 0.34 pounds less digestible protein daily than No. 5. Inasmuch as their average weights and the energy value of their rations were nearly equal, it would appear that, either the higher protein content of the ration of No. 5 resulted in no increased gain or that No. 1 required less protein for development. As shown by the table the protein metabolism of No. 5 was greater than that of No. 1.

It is seen that No. 4 made nearly as great gains in weight as No. 15 and greater gains than No. 5, yet the digestible protein in the ration of No. 4 was 0.12 pounds and 0.10 pounds less respectively than in case of those two animals. It is also seen that No. 4 retained more protein than either No. 5 or No. 15. However, the greater gains of No. 4 could be attributed to the greater energy content of his ration compared to the rations of Nos. 5 and 15. The greater quantity of carbohydrates in his ration might have protected the protein from being broken down and used as fuel material.

From these results it appears that an increase in protein affects chiefly the amount of protein broken down and excreted, and only to a minor degree the amount of gain. That differences in individuality determine the rate of growth and that the feed protein supplies material for that growth. A deficient protein supply tends to retard growth on account of a lack of material. An excess of protein, on the other hand, does not stimulate growth to any great extent, but a surplus is disposed of by being used as fuel material, the nitrogen appearing in the urine.

Chart 1 illustrates more clearly some of the results shown in table 9. The chart shows that the curves for protein retained in case of Nos. 13 and 1 to be substantially as high as those of the other animals, except No. 4, yet the curves for protein consumed for those two animals is much lower. Nos. 5 and 15 consumed the most protein, had the highest protein metabolism, but their curves for protein retained are not higher than the other animals.

The chart shows that No. 4 made greater gains than any animal except No. 15; that he consumed less protein than either No. 5 or No. 15; but that he retained more protein than any other animal.

The chart clearly shows that the quantity of protein retained depends upon the individual rather than upon the feed. It should be borne in mind, however, that if the protein supply is reduced to a maintenance ration the curves for protein digested, protein retained and protein excreted in the urine would coincide. In other words, there would be no protein stored up.

From table 10 it is seen that the calves which digested the most protein showed the greatest protein metabolism, and those which digested the least protein showed the smallest protein metabolism. It is also seen that with the exception of No. 13 at the bottom of the table there was not much difference in the amount of protein retained per thousand pounds live weight. Thus in five cases out of six an increased protein supply did not result in a greater amount of protein being retained, but, instead, resulted in an increased protein excretion.

Table 10. Summary Table of Protein Digestion and Metabolism. Nutritive Ratio and Average Weight.

No. of Animal	Protein in Feed	Protein in Feces.	Protein Digested	Protein Metabolism	Protein Retained	Protein retained per 1,000 lbs. wt.	Nutritive Ratio	Average Weight
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	0.618	0.245	0 373	0.179	0.194	1.043	1:5.36	186.0
13	0 827	0.349	0.478	0.193	0.285	0.961	1:6.20	296.7
15	0 880	0.352	0.528	0.212	0.316	0.991	1:8.20	318 7
5	1.094	0.403	0.691	0.529	0.162	0.717	1:3.30	226.0
6	1.126	0.324	0.802	0.518	0.284	0 934	1:4.24	304.0
13	1.308	0.380	0.928	0.803	0.125	0.382	1:3.28	327.0

No. 13 after being changed from a ration low in protein to one high in that nutrient retained less protein than on the low protein ration. He retained 0.125 pounds of protein on the high protein ration and 0.285 on the low protein ration. It would appear from these results that the high protein ration was disadvantageous.

From the standpoint of protein retained these results indicate that calves fed rations containing an amount of protein equal to that required by the Wolff-Lehmann feeding standards do not retain any more of that food nutrient than calves fed rations containing from 18 to 36 per cent less.

CONCLUSIONS.

1. The capacity for growth depends primarily upon the individual, and as long as the protein supply is adequate to supply material for growth a larger quantity does not cause a greater rate of growth except only to a minor degree. On the other hand a deficient protein supply limits growth.

2. Individuals vary in their requirements for protein. A normal protein supply for one animal is not necessarily a normal supply for another.

3. While the results by lots indicate that the greater protein supply of Lots 2 and 3 caused greater gains, a study of individual gains showed that individuality played a greater part than did the protein supply.

4. In respect to digestible protein, the average ration of Lot 3 conformed more nearly to the amount prescribed by the Wolff-Lehmann feeding standards than that of the other two lots, but a determination of nitrogen balance with two animals of each lot indicated that those of Lot 3 did not retain any more protein than those from the other lots.

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